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# Performance of Forage Soybean in the Southern Great Plains

S. C. Rao,* H. S. Mayeux, and B. K. Northup

## ABSTRACT

**Pasture for livestock in the southern Great Plains is often in short supply during the late summer. This study compared seasonal patterns in forage production, forage quality, and seed yield of three recently developed forage soybean [*Glycine max* (L.) Merr.] cultivars (Donegal, Derry, and Tyrone) to the seed cultivar Hutcheson. Inoculated seeds were planted at 60 kg ha$^{-1}$ in rows (20 m long) with 60-cm spacing, in June 2001, 2002, and 2003, after harvest of no-till winter wheat (*Triticum aestivum* L.). Whole plant samples were collected on six sample dates from approximately 52 to 120 d after seeding (DAS). At 120 DAS, forage soybeans Derry, Donegal, and Tyrone leaf and stem accumulations were 15, 46, and 47% and 43, 69, and 126% greater than that of Hutcheson, respectively. Seed soybean initiated flowering 15 d earlier than forage soybeans, resulting in lower leaf and stem yield. Forage quality of whole plants (N concentration and dry matter digestibility) of whole plant was similar across cultivars. Seed yield of Tyrone was lowest (690 kg ha$^{-1}$), as compared to Donegal (1180 kg ha$^{-1}$), Hutcheson (985 kg ha$^{-1}$), or Derry (939 kg ha$^{-1}$). Nitrogen concentration and digestible dry matter (DDM) of seed for all cultivars were similar. We concluded that forage soybean cultivars could provide greater leaf and stem biomass for livestock in the southern Great Plains during late summer and early fall when perennial warm-season grasses are less productive.**

A BASIC GOAL of grazing programs is to provide high-quality, year-round forage to reduce costs of storage and purchasing preserved forage or concentrate feeds, but no single crop has the potential to provide year-round forage. One of the traditional approaches to agricultural production in the southern Great Plains is based on grazing yearling stocker cattle on winter wheat. Wheat pasture is grazed during winter and early spring and is often used as a dual-purpose forage and seed crop. Warm-season perennial grasses such as bermudagrass [*Cynodon dactylon* (L.) Pers.] and Old World bluestem (*Bothriochloa* spp.) provide forage during late spring through early summer, but high-quality forage is unavailable from late July through November, as warm-season grasses become mature, and winter wheat is not yet available for grazing. Therefore, additional plant resources that can supply forage during this deficit period are needed to develop sustainable forage-livestock production systems.

Soybean was introduced into the USA from China in the mid 1800s as a potential forage crop (Arny, 1926; Caldwell, 1973) and has a long history as nutritious forage. Protein content of soybean hay generally ranges from 120 to 140 g kg$^{-1}$ for stems, 190 to 200 g kg$^{-1}$ for leaves, and 120 to 270 g kg$^{-1}$ for pods, depending on the stage of development (Miller et al., 1973). However, when the value of the oil seed climbed in the 1960s and 1970s, soybean production shifted almost exclusively to seed cultivars. Many producers are now grazing or harvesting immature soybean fields for hay. Devine and Hatley (1998) and Devine et al. (1998) recently developed several improved cultivars of forage soybean that could provide better grazing.

Little research has been conducted on the productivity and value of forage soybean in the southern Great Plains region. The objectives of this study were to compare and quantify leaf, stem, and pod production and the quantity and quality of each component of forage-type soybean cultivars.

## MATERIALS AND METHODS

Field experiments were conducted during the summer fallow period of 2001, 2002, and 2003 in a production system involving continuous no-till winter wheat near El Reno, OK, at the USDA-ARS Grazinglands Research Laboratory (35°40′ N, 98°00′ W, elevation 414 m). Soil at the experiment site was Brewer silty clay loam soil (fine-silty, mixed, superactive, thermic Pachic Argiustolls) with a pH of 6.6. Mean maximum and minimum temperatures during the June to October growing seasons were 37 and 20°C, respectively. The 25-yr (1978–2003) mean average rainfall during the growing season (June to October) was 411 mm. Average date of first killing frost (90% probability) was 2 November (Johnson and Duchon, 1995).

Cultivars used in this study were Donegal, Derry, and Tyrone forage-type cultivars (Devine and Hatley, 1998; Devine et al., 1998) and the common seed-type cultivar Hutcheson. Following seed harvest of no-till winter wheat in June, 26 kg ha$^{-1}$ of P was applied. No N fertilizer was applied. Because of extreme dry conditions in May and June of 2003, plots were irrigated (91 mm) to ensure emergence and establishment. Seeds were inoculated and planted 2 cm deep at the rate of 60 kg ha$^{-1}$ with a row spacing of 60 cm. Planting dates were 8, 10, and 11 June 2001, 2002, and 2003, respectively. Each plot was 3 m wide and 20 m long, with three replications of each cultivar. Rainfall and ambient temperatures were monitored continuously at the experimental site.

Aboveground, whole-plant samples were collected on six sampling dates from approximately 52 to around 120 DAS. Three randomly selected 0.5-m lengths of rows were clipped 2.5 cm above ground at each plot. Samples were collected at a new location on each sampling date. Plant samples were dried in a forced-draft oven at 65°C for at least 60 h or until constant dry weight was obtained. Samples were then weighed to determine dry matter content and separated into leaves and stems on the first four sampling dates and into leaves, stems and seedpods on last two dates.

All plant components were analyzed for N concentration with a complete-combustion N analyzer (Leco 1000, Leco

USDA-ARS, Grazinglands Research Lab., 7207 W. Cheyenne St., El Reno, OK 73036. Received 7 Oct. 2004. *Corresponding author (srao@grl.ars.usda.gov).

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**Abbreviations:** DAS, days after seeding; DDM, digestible dry matter.

**Table 1. Monthly precipitation and mean monthly ambient temperature for June through October, 2001 to 2003, and the 25-yr average, near El Reno, OK.**

| | Precipitation | | | | Temperature | | | |
|---|---|---|---|---|---|---|---|---|
| Month | 2001 | 2002 | 2003 | 25-yr average | 2001 | 2002 | 2003 | 25-yr average |
| | mm | | | | °C | | | |
| June | 39 | 60 | 91 | 125 | 24 | 24 | 22 | 26 |
| July | 31 | 23 | 89 | 55 | 30 | 26 | 30 | 29 |
| August | 93 | 56 | 63 | 66 | 27 | 27 | 27 | 28 |
| September | 75 | 169 | 27 | 90 | 20 | 22 | 20 | 24 |
| October | 6 | 150 | 50 | 75 | 15 | 12 | 16 | 16 |
| Total | 240 | 458 | 320 | 411 | | | | |

**Table 2. Combined analysis of variance of whole-plant, leaf and stem dry matter yield (DMY), N concentration, and digestible dry matter (DDM), for all years and sampling dates, for soybean cultivars at El Reno, OK.**

| | | DMY | | | N | | | DDM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | df | Total | Leaf | Stem | Total | Leaf | Stem | Total | Leaf | Stem |
| Rep (R) | 2 | NS† | NS | NS | NS | NS | NS | NS | NS | NS |
| Cultivars (C) | 3 | NS | ** | ** | NS | NS | NS | ** | NS | NS |
| Error (a) | 6 | | | | | | | | | |
| Years (Y) | 2 | ** | ** | ** | ** | ** | ** | ** | ** | NS |
| Y × C | 6 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Error (b) | 16 | | | | | | | | | |
| Sampling dates (D) | 5 | ** | ** | ** | NS | ** | ** | ** | ** | NS |
| D × C | 15 | ** | ** | ** | NS | NS | NS | NS | NS | NS |
| D × Y | 10 | ** | ** | ** | NS | ** | ** | ** | ** | NS |
| D × Y × C | 30 | ** | NS | NS | NS | NS | NS | NS | NS | NS |
| Residual | 120 | | | | | | | | | |

** Significant at the 0.01 level of probability.
NS, not significant at the 0.05 level of probability.

Corp., St Joseph, MI)[1] and for in vitro DDM by near-infrared reflectance spectroscopy (NIRS). Spectral data were collected on all samples; an average of 32 scans for each sample, with an NIR spectrophotometer model 6500 (Foss International, Silver Springs, MD), equipped with a static sample cup device. The NIR was calibrated by combining 12% of the samples from this study with spectra from a library of 350 soybean samples. In vitro digestible dry matter was determined for the NIRS calibration with the two-stage technique of Tilley and Terry (1963), as modified by Monson et al. (1969). Calibration and validation of equations for each plant component were done with InfraSoft International (Port Matilda, PA), using partial least squares regressions (Shenk and Westerhaus, 1991). Coefficients of determinations ($R^2$) of regressions were 0.97 or more.

All treatments were fixed in space and repeated on the same plot throughout the entire study period. Treatments were fixed in space to allow a second experiment to determine the effect of soybean on the following winter wheat crop. The cultivars were arranged in a randomized-complete block design with three replicates. A split-split plot model was used to evaluate the cultivars as the main plot-treatment [error a = (rep × cultivar)], years as the split-plot treatment (error b = rep × years within cultivar) and sampling date as the split-split plot treatment (error c = residual error). Analysis of seed variables was performed separately because of differences in sampling dates. All types of means were separated with the least significant difference (LSD) using the LS mean test and the level of significance was set at $P = 0.05$.

## RESULTS AND DISCUSSION

The amount and distribution of precipitation during the growing seasons varied among years (Table 1). Precipitation in the 2001 and 2003 growing seasons was 22 and 42% below the long-term average and 111% of the 25-yr average in 2002. Most of the precipitation in 2002 fell late during the growing season (September and October).

Cultivar, year, and sampling date effects produced 2- and 3-way interactions for most measurements of dry matter, leaf and stem N, and DDM (Table 2). Only year effects were significant for total N, and no significant effects were noted for stem DDM. Significant cultivar main effects were noted for seed yield, N, and DDM, and significant date × year interactions occurred for all three characteristics and date × cultivar effects for seed DDM (Table 3).

Discussion of the results in the following section is based on the order of statistical significance, which ranges from the highest-level interaction to the main effects of treatments. If there was a significant interaction, the main effects of the treatments involved in the interaction are not presented.

**Table 3. Combined analysis of variance for seed yield, seed nitrogen (N), and seed digestible dry matter (DDM).**

| | | Seed | | |
|---|---|---|---|---|
| Source of variation | df | Yield | N | DDM |
| Rep (R) | 2 | NS | NS | NS |
| Cultivars (C) | 3 | * | ** | * |
| Error (a) | 6 | | | |
| Years (Y) | 2 | ** | ** | ** |
| Y × C | 6 | NS | * | * |
| Error (b) | 16 | * | ** | ** |
| Sampling dates (D) | 1 | | | |
| D × C | 3 | NS | NS | ** |
| D × Y | 2 | ** | ** | ** |
| D × Y × C | 6 | NS | NS | NS |
| Residual | 71 | | | |

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability
NS, not significant at the 0.05 level of probability.

[1] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

**Table 4. Average aboveground accumulated dry matter (kg ha$^{-1}$) for cultivars at different sampling dates during the 2001 to 2003 growing seasons, for soybean cultivars at El Reno, OK.†**

| | 2001 | | | | 2002 | | | | 2003 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampling date | Derry | Donegal | Hutcheson | Tyrone | Derry | Donegal | Hutcheson | Tyrone | Derry | Donegal | Hutcheson | Tyrone |
| 1 August | 111 | 107 | 88 | 86 | 419 | 400 | 366 | 400 | 197 | 184 | 158 | 88 |
| 14 August | 160 | 130 | 94 | 138 | 675 | 740 | 595 | 542 | 416 | 501 | 300 | 278 |
| 27 August | 351 | 378 | 204 | 378 | 1007 | 943 | 1131 | 1131 | 768 | 900 | 514 | 553 |
| 10 September | 735 | 807 | 678 | 701 | 1797 | 1944 | 2072 | 1824 | 1724 | 2343 | 796 | 1403 |
| 24 September | 1596 | 1380 | 976 | 1629 | 2132 | 3043 | 2205 | 2181 | 3765 | 4392 | 2681 | 2504 |
| 9 October | 2406 | 1671 | 1573 | 2414 | 2334 | 2970 | 2405 | 2764 | 2329 | 5406 | 3568 | 4616 |
| LSD(0.05) | | 406 | | | | 376 | | | | 838 | | |

† LSD are for mean separations for cultivars within years.

## Whole Plant Responses

Total aboveground biomass of all cultivars increased from the early to final harvest dates in all three growing seasons. In general, total plant yield in year 2001 was significantly lower ($P = 0.05$) when compared with 2002 and 2003 (Table 4). This could be attributed to drier conditions during the 2001 growing season (Table 1). Total accumulation of aboveground dry matter differed among cultivars, but the differences were not consistent over sampling dates or growing seasons. In general, dry matter accumulation for all cultivars was minimal until mid- to late-August. Rate of dry matter accumulation was greater for all cultivars during the later growth stages (September to October). At the last two sampling dates, in September and October, whole plant forage yields of all cultivars ranged from slightly less than 1 to 2.4 Mg ha$^{-1}$ in 2001, the year with lowest yield, and 2.3 to 5.4 Mg ha$^{-1}$ in 2003, the year with highest forage yields. In 2001, yield of the forage cultivars Derry and Tyrone were 52 and 53% greater at the last sampling date than Hutcheson and Donegal. However, Derry was similar to Hutcheson in 2002 and 2003, when total above ground biomass for Donegal and Tyrone were 23 and 14% and 51 and 29% greater than Hutcheson, respectively (Table 4). Tyrone produced greater total dry matter at the last sampling date in 2001 and Donegal and Tyrone in 2002 and 2003, irrespective of environmental conditions.

Among the cultivars, whole plant DDM was greater in the seed cultivar at 783 g kg$^{-1}$, compared with 757 g kg$^{-1}$ for Tyrone. In general, the difference in DDM between Donegal and Hutcheson was negligible, since they belong to same maturity group (MG) MG 5. Donegal and Hutcheson produced more seed than Derry (MG 6) and Tyrone (MG 7).

## Leaf, Stem Yield, and Quality

Similar to total dry matter, leaf, and stem yields were significantly lower ($P < 0.05$) in 2001 than in 2002 or 2003 (Fig. 1A). In 2002, precipitation was unusually high during the last two sampling dates, resulting in lower leaf and stem dry matter accumulation. Growth rates of all cultivars were greater ($P = 0.05$) during the last two sampling periods in 2003. Linkemer et al. (1998) indicated that early reproductive stages of soybean are

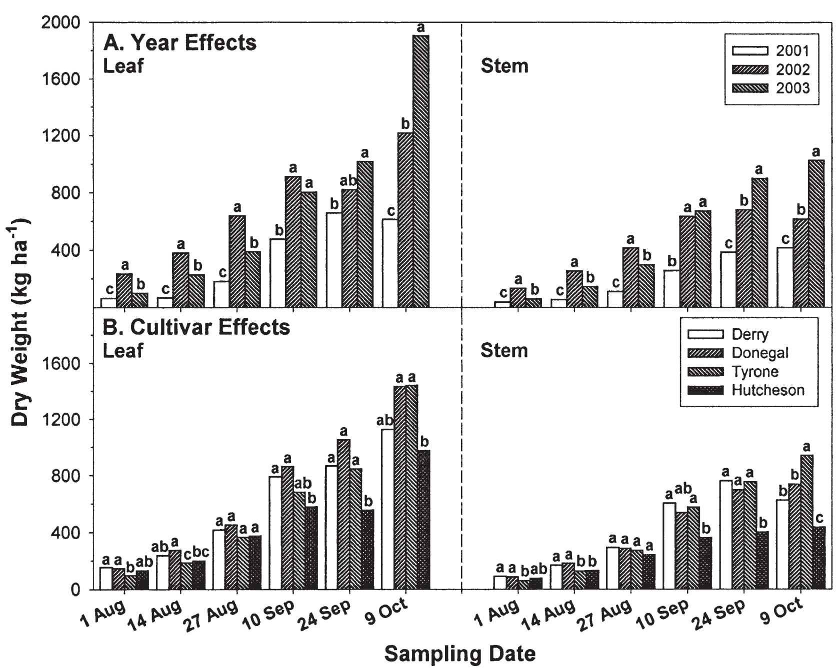


**Fig. 1. Average soybean leaf and stem dry weights on different sampling dates for (A) cultivars averaged across years, and (B) cultivars averaged across years. Bars with the same letter for a given date were not significantly different ($P = 0.05$)**

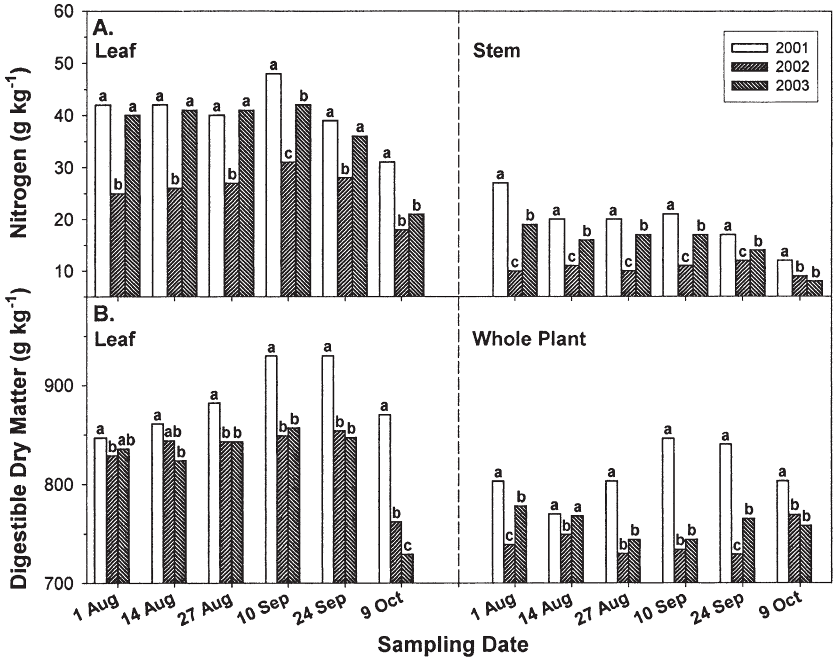


**Fig. 2. Soybean (A) leaf and stem nitrogen concentrations at different sampling dates for years, and (B) leaf and whole plant digestible dry matter at different dates for years averaged across cultivars. Bars with the same letter for a given date were not significantly different ($P = 0.05$).**

most sensitive to excess precipitation and such conditions result in reduced crop growth.

Accumulation of leaf and stem dry matter varied by sampling date (Fig. 1B). The cultivars Derry and Donegal had more leaf and stem dry matter than the Hutcheson for two of the three years. During early growth (until 27 August.), Derry and Donegal had 17 to 37% greater leaf and 17 to 41% higher amounts of stem dry matter than Hutcheson or Tyrone. Tyrone was slow in establishment and early growth, which could be attributed to its late maturity. However, by late August, the differences in leaf and stem dry matter among the forage cultivars were minimal. All three forage cultivars (Derry, Donegal, and Tyrone) had higher leaf and stem dry matter after September than the seed type (Hutcheson). Among the forage types, Derry, Donegal, and Tyrone had 15, 46, and 47% greater leaf, respectively, and 43, 69, and 216% greater stem than Hutcheson, at the last sampling date.

A significant ($P = 0.05$) difference in N concentration of leaves and stems was observed among growing seasons (Fig. 2A). Nitrogen concentration in stems of all cultivars was lower as compared with leaves. Among growing seasons, leaf N was significantly greater in 2001 and 2003 than during 2002. Leaf N averaged across sampling dates in 2001 was 40.3 g kg$^{-1}$ as compared with 25.8 and 36.0 g kg$^{-1}$ in 2002 and 2003, respectively. The lower leaf N observed during 2002 for the first four sampling dates could be attributed to possible dilution of N in greater leaf and stem biomass. The N concentration in stems followed a pattern similar to leaf N and was lower in the first four sampling dates of 2002. These stem N concentrations were similar to those reported by Hintz et al. (1992).

Similar to leaf N, DDM of leaves and whole plants were similar at all sampling dates in 2001 (Fig. 2B) as compared with 2002 and 2003. Higher DDM in 2001 could be attributed to lower whole plant biomass accumulation.

**Table 5. Seed yield across years, seed N, and seed digestible dry matter (DDM) for soybean cultivars averaged across dates, at El Reno, OK.**

| Cultivars | Seed yield | Seed N | | | Seed DDM | | |
|---|---|---|---|---|---|---|---|
| | | 2001 | 2002 | 2003 | 2001 | 2002 | 2003 |
| | kg ha$^{-1}$ | g kg$^{-1}$ | | | | | |
| Derry | 939 ab† | 33 a | 47 a | 55 a | 848 a | 868 a | 910 ab |
| Donegal | 1180 a | 31 a | 42 b | 49 b | 853 a | 885 a | 887 bc |
| Hutchinson | 985 a | 30 a | 42 b | 47 b | 833 a | 872 a | 914 a |
| Tyrone | 690 b | 33 a | 43 b | 47 b | 842 a | 889 a | 880 c |

† Means in a column followed by the same letter do not differ significantly at the 0.05 level (LDS test).

## Seed Yield and Quality

Seed yield, averaged across growing seasons and sampling dates, was highest for Donegal (1180 kg ha$^{-1}$) and least for Tyrone (690 kg ha$^{-1}$) (Table 5). Seed yields of Donegal and Derry did not differ significantly from that of Hutcheson. Lower seed yield for Tyrone could be attributed to its prolonged vegetative growth and shorter pod-filling period, which resulted in more leaf and stem yield and fewer pods. Among the cultivars, significant differences in seed N and DDM were observed among cultivars and growing seasons. Seed N was similar during 2001 for all cultivars. Seed N of Derry was higher in 2002 and 2003 (Table 5). Seed DDM was similar for both forage and seed soybeans in 2001 and 2002 but varied among cultivars in 2003, where Hutcheson produced more DDM (914 g kg$^{-1}$). The lower seed DDM for Tyrone and Donegal might be associated with lower translocation of nutrients to seed. These results were

**Table 6. Seed yield, nitrogen (N) content and digestible dry matter (DDM) averaged across cultivars at different sampling dates during the 2001–2003 growing seasons.**

| | Seed yield | | Seed N | | Seed DDM | |
|---|---|---|---|---|---|---|
| **Year** | **24 September** | **9 October** | **24 September** | **9 October** | **24 September** | **9 October** |
| | kg ha$^{-1}$ | | g kg$^{-1}$ | | | |
| **2001** | **354 c†** | **988 b** | **31 b** | **33 c** | **863 a** | **825 b** |
| **2002** | **852 b** | **692 c** | **35 a** | **56 b** | **786 c** | **971 a** |
| **2003** | **1419 a** | **1385 a** | **35 a** | **62 a** | **816 b** | **980 a** |

**† Means in columns followed by the same letter for each variable do not differ significantly at the 0.05 level (LSD test).**

similar to those reported by Sheaffer et al. (2001), who showed that adapted seed soybean cultivars matured earlier and had greater pod numbers than forage soybeans.

Significant differences ($P = 0.05$) in seed yield were observed during both sampling dates (Table 6). Mean seed yield averaged across cultivars and sampling dates varied among growing seasons. Seed yields averaged across cultivars were significantly greater in 2003 than 2001 or 2002. In 2001, seed yields were significantly lower on 24 September than during the 2002 and 2003 growing seasons. At physiological maturity (last sampling date), seed yield in 2003 was highest (1385 kg ha$^{-1}$) compared with 2001 (988 kg ha$^{-1}$) and 2002 (692 kg ha$^{-1}$). Lower seed yields in 2002 may be attributed to increased precipitation during the late growth stages. Near-normal temperatures and precipitation in late September and early October of 2003 may have contributed to increased seed yield and seed N concentration. Griffin and Saxton (1988) reported that excess precipitation after flowering and early seed filling stages decreased seed yield. Similarly, Linkemer et al. (1998) observed declines in seed yield from 2453 to 1550 kg ha$^{-1}$ when 3 to 5 cm of rain was received during the early pod-filling stage. Seed DDM in 2002 and 2003 was highest on the final date, while seed DDM in 2001 was highest on the earlier date. The lower seed DDM at the later sampling date in 2001 could be attributed to below normal precipitation and low seed N concentration.

## CONCLUSIONS

These results suggest that environmental conditions, especially precipitation distribution, played an important role in the performance of both seed and forage soybeans. Late-maturing forage cultivars Derry and Tyrone produced greater total biomass at later growth stages (September and October) than other cultivars, even under dry environmental conditions. Among the forage soybean cultivars, Tyrone had greater leaf and stem yields and lower seed yield at final harvest. The low seed yield for Tyrone could be attributed to a short seed filling period. Nitrogen concentration and DDM of whole plants was greater for seed soybean Hutcheson than all forage soybean cultivars including Tyrone. Nutritive values (N and DDM) were similar for all forage cultivars. We concluded that Tyrone has the potential to provide high quality and quantity of forage in late summer and early fall, when other forages in the southern Great Plains Region are less productive.

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